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Public awareness and willingness to adopt ground source heat pumps for domestic heating and cooling

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ABSTRACT

Nowadays, residential heating and cooling are responsible for a significant part of the total global energy consumption. In order to create environmentally friendly buildings, the application of renewable energy technologies is recommended. Such a technology is GSHP[1] systems. This study examined the level of consumers' awareness on this technology, their perception on considering installing such a system, as well as the factors influencing the above issues. According to a logistic regression analysis, knowledge concerning the use of a GSHP system for residential use is positively related to the existence in the residence of a person with an occupation or interests associated to environment, technology or engineering, as well as the awareness about RES[2] issues and higher educational level. Also, considering installing a GSHP system is positively related to the existence in the residence of a person with an occupation or interests associated to environment, technology or engineering, awareness on RES and alternative technologies, as well as younger age groups, higher income groups, university and technical vocational education graduates.

Contents

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[1] Ground source heat pump.
[2] Renewable energy sources.

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1. Introduction

The energy consumption of households is constantly rising due to the increased demand for amenities and the more time spent indoors [1]. Buildings consume about 40% of global energy consumption, while the percentage of the residential sector approaches 25% of total consumption [2,3]. In Greece, 29% of total energy is consumed by households [3]. A big part of residential energy is used for space heating, cooling, air conditioning as well as hot water production. The distribution of residential energy consumption between different categories may vary depending on the climate zone. It may vary from 40% for heating, 20% for hot water, 8% for air conditioning [4] to 57% for heating and 25% for hot water [5]. Generally, in developed countries the average for heating, cooling and air conditioning accounts for 50% of the residential energy consumption, which corresponds to approximately 20% of the total energy consumed [1].

The reduction of energy used for heating and cooling can provide a solution against increased energy consumption of the residential sector. A sustainable option is the use of innovative technologies based on RES, forming an efficient and effective solution for energy reduction [2,5–12].

GSHP systems are technologies that can contribute in a sustainable manner to the reduction of energy consumption of buildings and their independence from fossil fuels by covering their heating, cooling and hot water needs. GSHP are very efficient compared to conventional systems, while their operating principle is based on the fact that unlike air, earth has a constant temperature during the whole year. During winter the system transfers thermal energy from the ground to the building to heat it, while during summer it cools the building by discarding thermal energy to the ground. Moreover, it can provide hot water without extra energy consumption. Although GSHP systems usually have a higher installation cost than conventional systems, their operation and maintenance costs are significantly lower. So, the payback period of the installation can be very low, combining financial benefits with environmental protection through reduced GHG emissions [13–17].

Diffusion of GSHP systems is still in an early stage, since the space heating and cooling sectors are mainly occupied by conventional technologies. However, the technology has great development potential as, among other advantages, it can be installed in any area since its application is irrelevant of the underground temperature. The regions in which the technology is more developed are North America and some European countries (Germany, Switzerland, Austria, France, and Scandinavian countries), while development also occurs in some other countries like Japan and Turkey [13–15]. Regarding to the EU market, in 2012 98,807 GSHP units were sold, thus exceeding the number of 990,000 total installed units. On the contrary, due to the financial crisis and the decline of the construction activity there was a decrease in sold units compared to 2011 by 8.9% [18]. Diffusion of this technology in Greece is rather low, with available data showing that in 2013 there were 800 GSHP systems installed in Greece, with estimations giving a total number up to 1,000 units [19]. After all, public awareness on renewable energy technologies in Greece has been found to be incomplete [20,21].

The present study attempts to answer the questions of how informed the public in Greece is about the GSHP renewable energy technology, and how willing it is to adopt it. Specifically, the aim of this study is to identify the factors that affect whether the consumer knows the technology, as well as the factors that will lead him to consider installing the technology in his residence.

2. Factors influencing residential heating system selection

The initial work examining the factors that have an influence on the selection of residential heating systems involved the U.S., and used Census data in order to examine the possible influence on the selection process of demographic and socioeconomic characteristics and factors such as the installation and operation cost of the system [22–25]. During last years, from 2000 until now, the number of studies conducted on the specific issue has increased. These studies emphasize not only on the socioeconomic, spatial and residential characteristics, but also on how consumer's behavior, preferences and attitudes can affect the selection process. Additionally, the majority of these studies focus on specific types of heating systems based on renewable energy technologies. Countries that have been mostly studied this way are mainly the Scandinavian: Norway [26–34], Sweden [35–42] and Finland [43–46], as well as Germany [47–55] and the UK [56–60]. Table 1 presents the identified studies that involve residential heating selection factors, based on the country that is being examined. The ranking (ascending to descending) is based on the total number of studies found for each country.

A clear classification of the work can be made regarding the data and the variables that are being examined. Studies can be divided between those using real preferences using Census data, or data from questionnaires regarding real decisions, and those which take into account stated preferences regarding hypothetical decisions using data obtained from the appropriate questionnaires [52]. Regarding the work using stated preferences on hypothetical decisions, usually the willingness to pay (WTP) for specific technologies is examined through choice experiments [46,49,51,59,60,66,70,72].

Work regarding real preferences or decisions can be categorized based on the type of variables used to examine the heating system selection process. There are studies [22–25,48,61–65,68,69,76,77] that use only socioeconomic, spatial and residence characteristics, as well as some characteristics related to the heating system, such as price of fuels [22,62,76], investment cost [22–24,61,63,68], operating cost [22–25,61,63] and physical work involved in using a system [68] in order to examine the selection process. On the other hand, there are studies that take into account not only the aforementioned factors, but also examine the influence of consumers' behavior, lifestyles, attitudes, intentions, norms and preferences for specific heating systems characteristics on the selection process [26–45,47,50,52–58,67,71,73–75,78].

Many of the studies that also examine behavioral and preference factors use theories on innovation and technology diffusion and consumer behavior in order to construct a theoretical basis and explain the context in which consumers make their choices regarding residential heating systems [26,28–31,35,38,39,42–45,52,53,55,72,78]. Theories that are more commonly used are Diffusion of Innovations (DoI) Model from Rogers [79] and Theory of Planned Behavior (TPB) from Ajzen [80]. According to Rogers [79], the factors that can have a positive effect to the diffusion of an innovative technology can be particularized to five: “relative advantage, compatibility, complexity, trialability and observability”. On the

Table 1
Categorization of studies based on country examined.

Norway	[26–34,61–63]
Germany	[47–55,64,65]
Sweden	[35–42]
USA	[22–25,66,67]
Finland	[43–46,68,69]
UK	[56–60]
Canada	[70,71]
Ireland	[72,73]
New Zealand	[74,75]
Italy	[76]
Slovenia	[77]
Switzerland	[78]

other hand, the Theory of Planned Behavior [80] deals with the connection between beliefs and behavior, stating that attitude toward behavior, subjective norms, and perceived behavioral control form the behavioral intentions and behaviors of an individual. Other theories that are used to create a theoretical framework on consumers' residential heating system selection are Consumer Perceived Value (CPV) [81], Technology Acceptance Model (TAM) [82], Perceived Characteristics of Innovations (PCI) [83] and Comprehensive Action Determination Model (CADM) [84].

Factors affecting the residential heating selection can be divided into socioeconomic characteristics, spatial characteristics, residence characteristics, as well factors related to consumers' behavior, attitudes and preferences for specific heating systems attributes. The socioeconomic and demographic characteristics that have been more frequently found to statistically significantly affect the heating system selection are income [25,27,29,32,33,53,54,56,57,60,62,64,65,67,68,76], age [25,27,29,32,33,37,43,46,49,51,53,54,60,68] and educational level [27,29,47–49,51,54,65,67,76]. Other socioeconomic characteristics that have been found to have an influence are household size [32,47,48,56,57,64,65], presence of children in the house [65,76], number of children [68] and gender [43,54]. Regarding the residence characteristics, those that have been found to have an influence on the heating system selection are size of the house or number of bedrooms [25,32,48,56,57,54,62,63], type of the residence [32,33,37,56,57,62,63,65], year of construction of the residence [48,54,62,65,76], ownership [48,65,76], years living in the residence [33], infrastructure [54], renovations [65] or retrofits for improving energy efficiency [76]. The spatial characteristics that have an statistically significant effect are region [27,29,49,51,54,65,76], area type (urban/rural) [33,54,65,76], climate [32,48] and whether the location has “green” areas [76].

Factors related to consumers' behavior, attitudes and preferences for specific heating system attributes are divided in seven categories, which have been created, based on the six categories that Michelsen and Madlener [52] use in their work. The categories in which the factors can be placed are (i) economic aspects (e.g., investment cost, operation cost), (ii) environmental considerations and energy saving (e.g., energy efficiency, environmental concerns/attitude), (iii) energy supply security (e.g., independence from conventional fuels, security of fuel supply), (iv) comfort considerations and esthetics (e.g., functional reliability, indoor air quality, time and effort needed for operation/maintenance), (v) general attitude (e.g., compatibility with habits and routines), (vi) social reasons and information/knowledge (e.g., time required to collect information, social subjective norms) and (vii) supplier issues (e.g., service by suppliers/vendors, period of guarantee). Table 2 presents the factors that have been found to have an effect on the residential heating system selection, on the basis of the seven categories that have been created.

A distinction of the literature can be made on the basis of the type of the heating systems considered in each case. There is a number of studies that either generally examine the heating system selection process and factors, or examine a number of specific system types, without however focusing specifically in a particular one [22,24,47,49,50,51,61–65,68–70,76,77]. On the other hand, there are studies that focus on the research of specific heating system types, with literature review indicating that emphasis is being given to alternative options such as district heating [36–42,46], heat pumps [27,30,32,34,36,38–42,46,54,55,58,59,74,75] and systems utilizing renewable energy sources. As to the latter, work on wood stoves and boilers [23,26,32,46,56–58,71,78], biomass (pellet) stoves and boilers [27–32,34–36,38,39,41–46,54,55,58,59,72], firewood [33,66], ground source heat pumps [36,38–42,46,58,74,75], solar thermal [48,53,59,60,67], conventional systems assisted by solar thermal [54,55], air source heat pumps [27,32,34], or on various RES systems [73] has been detected.

Focusing on the studies that specifically examine the ground source heat pump residential heating systems, the following can be reported: Mahapatra et al. [36,38–42] in their work for Sweden have found that bedrock heat pumps are perceived to be better than district heating, pellet boilers and resistance heaters regarding GHG emissions, market value of the house, environmental benignity, security of fuel supply and annual cost of heating, while respondents would rather recommend heat pumps possibly due to their relative advantages over other heating systems. Rouvinen and Matero [46] found that in Finland there is an overall preference for ground heat and district heat and that factors that influence ground heat adoption are income, investment and operating cost of the system, CO_2 emissions, and unobserved factors such as reputation and reliability. Doody and Becker [74,75] identified GSHP as the application with the most potential for residential houses in New Zealand, while benefits identified from the respondents are efficiency, ability to heat and cool the home, ease of use, convenience, safety and indoor air quality. In an UK study, Caird and Roy [58] report that GSHP adopters are satisfied regarding system reliability, pleasure from using low carbon energy, appearance, and operation and maintenance costs. Kennedy and Basu [73] find that in Ireland geothermal technologies are more attractive for consumers mainly when building a new house, which may explain the low level of the technology diffusion, whereas GSHP were seen by consumers as an option with a high capital cost.

3. Materials and methods

3.1. Questionnaire

A four-paged questionnaire was used to conduct a survey. The questionnaire consisted of five sections. In section 1 the participants were asked to provide some information related to demographic characteristics, such as gender, age, marital status, educational level, occupation and monthly family income. In section 2 the participants had to fill in information about their dwelling; year of construction, type, size, number of persons living in it, number of children, number of elderly. In section 3 the respondents provided information regarding to their heating and cooling system; type, year of installation and person responsible for the decision of installation. Also, in the 3rd section the participants were asked to evaluate the function and the economic characteristics of their heating and cooling system. In section 4 the respondents evaluated different factors that can influence their decision on which heating system to select. The factors included were derived from the empirical work that is identified and presented in Section 2. Regarding the questionnaire, the factors were divided into six categories; five of them were relevant to the systems' characteristics: economic factors, technical features, comfort and esthetics, environment and security, information. The last category included socioeconomic factors and factors based on Rogers [79] diffusion theory. Respondents evaluated each factor using a five-degreed Likert scale, from “1 = not at all” to “5 = very much”. Section 5 consisted of questions regarding to the knowledge of the participants about environmental issues, renewable energy sources, geothermal energy and geothermal heat pumps.

3.2. Data collection

The survey took place between 15 December 2011 and 31 January 2012 in two municipalities of Attica, Greece. The two municipalities, Sarónicós and Lavreotikí lie at the south part of Attica prefecture, south from Athens. The specific municipalities were selected for the study because of the high percentage of

Table 2
Influential factors related to consumers' behavior, attitudes and system attribute preferences.

Economic aspects	Operation cost [27,29,32,36,38–42,46,54,56–60,70,71,74,75] Investment cost [29,36,38–42,46,49,51,54,55,59,60,70,71,74,75] Grant/subsidies [26,40,49,51,54–57,70,74,75] House market value [32,36–42,74,75] Current and expected future energy prices [29,30,32,34,47,55] Payback period [49,51,55,74,75] Total cost [28,31,34,54,55] Maintenance cost [36,54,55,59,60]
Environmental considerations and energy saving	Environmental concerns/attitude [26,28,29,53–57,67,70,71,73] Energy efficiency [49,51,54,56,57,74,75] Greenhouse gas emissions [32,38–42,57] Environmental benignity [36,38–42,72] CO_2 savings [46,49,51,58,74,75] Ecological aspects [47,50] Local air quality [32] Labels indicating energy efficiency [70] Fine particle emissions [46] Health risks[71]
Energy supply security	Security of fuel supply [27,29,36,38–40,42,55] Independence from conventional fuels [54,72] Fuel stability [34]
Comfort considerations and esthetics	Functional reliability [28,30,34,36,38–42,58,70,73–75] Indoor air quality [27,29,30,32,34,36,38–40,42] Time and effort needed for operation/maintenance [26,29,31,32,34,46,55] System automation [36,38,39,40,42] Ease of use [54,55,74,75] Convenience/inconvenience [47,59,60,71] Appearance [32,37,57,71] Performance [31,34,58,72] Comfort [33,70,74,75] Ease of installation [74,75] Heating effectiveness [26,71] thermal comfort [30,37] Fuel storage [71] Safety [71] Responsiveness (time needed to reach desired temperature) [70] Quality of living conditions [55]
General attitude	Compatibility with habits and routines [28,55,72,78] Lifestyle [33] Job, hobby or interests related to the environment/low carbon technologies [58]
Social reasons and information/knowledge	Social subjective norms [26,53,55,72,78] Time required to collect information [36,38–40,42] Understanding how the technology works [55,74,75] Recommended by others [29,59,60] Knowledge of the system [53,72,78] Friends and family have installed it [74,75] Recommendation of an independent energy adviser [49,51] Decision strategy: repetition-social comparison [27] Desire to improve image [55] Number of peers [55] Visibly demonstrate environmental commitment [58] Complexity [72]
Supplier issues	Service by suppliers/vendors [30,31,73] Contract length [59,60] Period of guarantee [49,51] Fuel supplier close to the house [34]

detached houses in the area. One of the aims of the study was to examine whether the house owners have considered installing a residential GSHP system for heating/cooling, so a survey in a mainly urban area with many apartment buildings (in which GSHP systems are not common) would not serve the purpose of the study.

The questionnaires were randomly distributed to households of seven different towns of these municipalities. The towns were Anávissos, Kalývia, Lagoníssi, Palaiá Phókea and Saronída from the municipality of Saronicós and Keratéa and Lávrio from the municipality of Lavreotikí. At the end of the distribution and collection process, 201 questionnaires had been collected, which comprise the population of the survey.

3.3. Data analysis

Statistical analysis was performed using SPSS 17.0 for Windows. Chi-square (χ^2) test of independence was performed to derive relations between variables (with p-value < 0.05). The non-parametric Mann–Whitney U test was used to examine if there were any significant differences between the group of participants that have considered installing a GSHP system and those that have

not, with respect to the factors that influence a consumer to select a heating system for his residence. In addition, two binary logistic regressions were performed. The first one has as dependent variable the possibility of someone knowing about GSHP systems for residential heating and cooling and the second one has the possibility of someone considering installing a GSHP for residential heating/cooling.

4. Results

4.1. Overview of the results

Profile analysis showed that 54.7% of the respondents were women, average age of the participants was 40.27 (median: 39, min/max: 18–80) and 58.8% were married. Regarding to the educational level, 26% of the respondents were high school graduates, 24.5% had graduated from a technical vocational educational institute and 24% had a university degree. As for their occupation, 53% were self-employed, 21% were employees in private companies and 10% were public servants. 28.1% stated that someone that lives in the residence (including themselves) had an occupation or interests that were related to environment, technology or engineering. Regarding to the monthly family income, 19.8% stated that it was between 501 and 1000€, 19.8% between 1001 and 1500€, while 15.8% that it was between 1501 and 2000€.

The majority (85.5%) of the respondents lived in a privately owned house, with 41.6% staying in a detached house and 18.3% in a 2-storey house. The average house had a surface of 117.93 m^2 (median: 100, min/max: 25–450). Average year of construction of the residences was 1991 (median: 1990, min/max: 1948–2010), while average years of accommodation were 14.41 (median: 11, min/max: 1–50). Referring to the main heating system, 79.6% was using an oil boiler, 13.4% air condition and 8% a fireplace, while 86.6% of the respondents stated that they used air condition for cooling. The average year of the main heating system installation was 1997 (median: 1999, min/max: 1970–2011) and for the cooling system 2003 (median: 2005, min/max: 1981–2011).

The factors that respondents believed that affect them most during the process of selecting a heating system for their house were functional reliability, lifetime of system, heating/cooling with only one system and security during operation, while the factors they believed that affect them the least were changes of the house market value because of the installation of a certain system, recommendations from others on a specific system and time needed for collecting information (Fig. 1).

Regarding the levels of information, 76.5% of the respondents stated that were generally informed about environmental issues, while the percentage for knowledge regarding issues related to renewable energy was 63.5%. Less than half (41.7%) of the respondents answered that know what geothermal energy is and 39.3% knew that geothermal energy can be used for residential heating and cooling. On the other hand, 23.7% knew that GSHP can be used for residential heating and cooling, while 8.6% had made thoughts of installing such a heating/cooling system. Most of the respondents that stated that know about GSHP systems were informed about them through

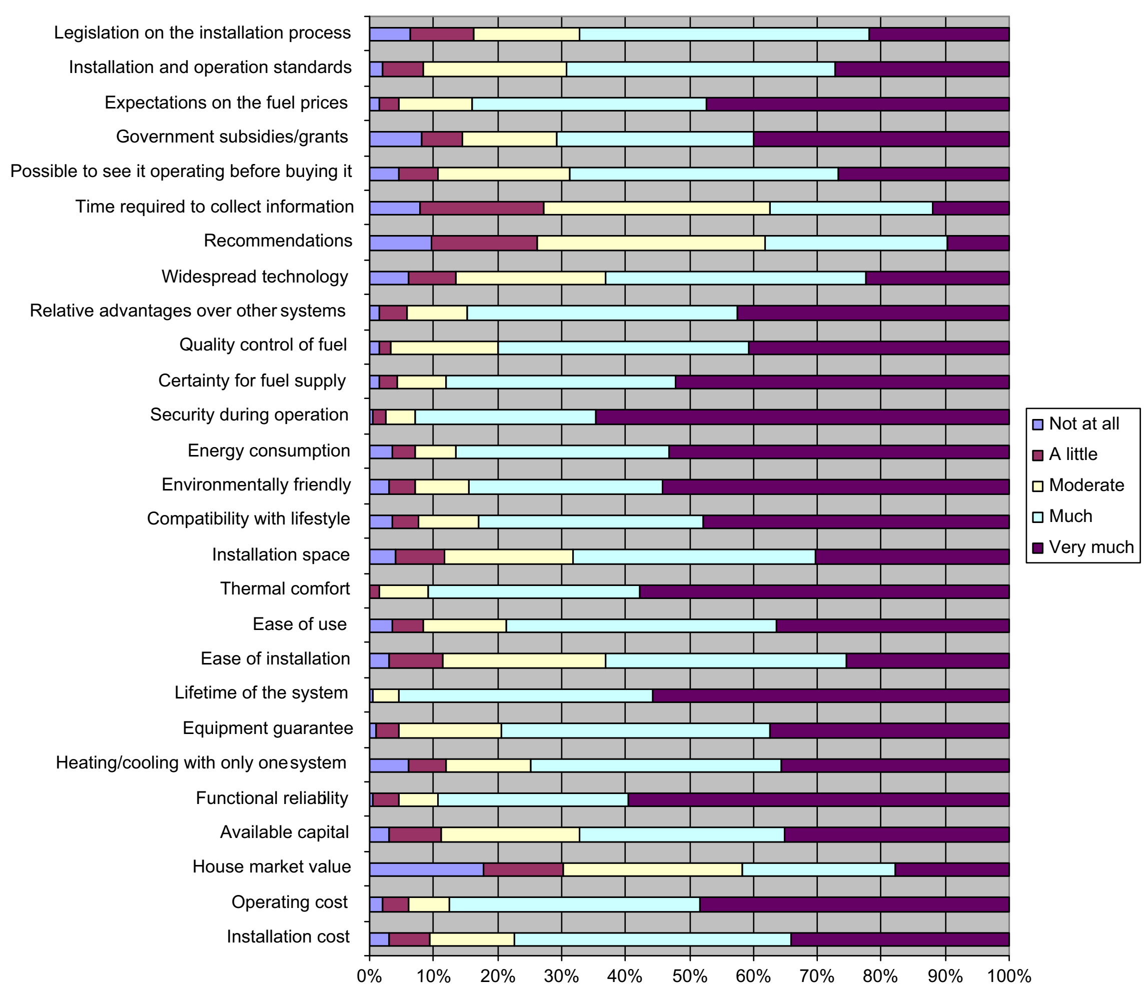

Fig. 1. Factors influencing residential heating system selection.

Table 3
Chi-square tests for independence (p-values)—demographic characteristics.

	Do you know what geothermal energy is?	Do you know that geothermal energy can be used for residential heating/cooling?	Have you heard about geothermal heat pumps?	Do you know that GSHP can be used for residential heating/cooling?	Have you considered installing a GSHP system for residential heating/cooling?
Gender	0.085	0.011**	1.000	1.000	0.354
Existence of a person living the residence with an occupation or interests related to environment, technology or engineering	0.059	0.019**	0.028**	0.000***	0.025**
Environmental awareness	0.757	0.946	0.957	0.360	0.226
Energy saving actions	0.778	0.987	0.081	0.382	0.216
Age	0.625	0.139	0.757	0.387	0.684
Educational level	0.000***	0.006***	0.062	0.007***	0.406
Monthly family income	0.199	0.294	0.882	0.880	–
Marital status	0.216	0.436	1.000	0.484	0.938
Occupation	0.139	0.377	0.366	0.196	–

–: Uncountable

*** Significance: $p \leq 0.01$.

** Significance: $p \leq 0.05$.

Internet (57.14%). Respondents that stated that had considered installing such a system report two main reasons for not installing it: high installation cost and disruption of the house during the installation process (for already constructed houses).

4.2. Chi-square tests for independence

Chi-square tests were conducted in order to identify statistically significant relationships between socioeconomic characteristics of the respondents and variables that represent knowledge about different issues. Knowledge about geothermal energy was positively related to educational level, while knowing that geothermal energy can be used for residential heating/cooling was found to be significantly related to gender, educational level and the fact that a resident of the dwelling has an occupation related to environment, technology or engineering. This demographic factor was also indicated to be positively related with knowledge about geothermal heat pumps, knowledge about the use of GSHP for residential heating/cooling and consideration on installing a residential GSHP system for residential heating/cooling. Knowledge about GSHP was also significantly positively related to educational level (Table 3).

According to the theoretical background, residence characteristics may affect the decision on which heating or cooling system will be chosen, as it has been reported in Section 2. Chi-square tests for independence were conducted between the variable that represents the question "have you considered installing a GSHP system for residential heating/cooling?" and variables that represent characteristics of the residence, in order to see if any of these characteristics influenced the respondent on his thoughts. No statistically significant relations between the examined variables were found.

4.3. Mann–Whitney U test

Except from the demographic and residential characteristics, there are also other factors that can influence consumers' decision on which heating system to select. These factors may be related to the system: economic factors, technical features, comfort and esthetics, environment and security, information, or may be socioeconomic factors or factors related to diffusion of new technologies. Mann–Whitney U tests examined if there were any significant differences between the group of participants that have considered installing a GSHP system and those that have not, with respect to the factors that influence a consumer to select a heating system for his residence. For the 27 different factors that had been examined, three had been found to be different between the two groups. These three factors were lifetime of the system ($p \leq 0.10$), energy consumption ($p \leq 0.05$) and security during operation ($p \leq 0.05$) (Table 4). Based on their means, these three factors had the highest rank among all factors, according to the answers of the group that has considered installing a GSHP system.

4.4. Logistic regression models

Two logistic regression models were developed. The first had as dependent variable the possibility of someone knowing about the use of GSHP systems for residential heating and cooling and the second had the possibility of someone considering installing a GSHP for residential heating/cooling.

4.4.1. Knowledge about the use of GSHP systems for residential heating/cooling

The likelihood of someone knowing about the use of GSHP systems for residential heating and cooling was estimated with the help of a binary logistic regression model, with dependent variable knowledge (residential_GSHP: yes or no) and independent variables the fact that someone in the residence has an occupation or interests related to environment, technology or engineering (related: yes or no), awareness on issues related to renewable energy sources (RES_awareness: yes or no) and level of education (education: low, medium, or high). The results showed that:

$$\text{Predicted logit of (residential\_GSHP)} = -4.119 + 1.139(\text{related}) + 1.437(\text{RES\_awareness}) + 0.330(\text{education})$$

According to the model, which explained about 24% of the variability of the dependent variable, the log of the odds of someone knowing about the use of GSHP systems for residential heating and cooling was positively related to the fact that someone in the residence has an occupation or interests related to environment, technology or engineering ($p < 0.01$), to awareness about RES issues ($p < 0.01$) and to educational level ($p < 0.05$).

More specifically, the odds someone that lives in a residence with a person that has an occupation or interests related to environment, technology or engineering to know that GSHP systems can be used for residential heating and cooling was 3.124 ($= e^{1.139}$) times greater than the odds of someone that lives in a house where no one has an occupation or interests related to environment, technology or engineering, regardless of the

Table 4
Factors that influence consumers' option—Mann–Whitney *U* test.

	Mean		Mean		*Z*	Asymp. Sig. (2-tailed)
	Yes	Std. deviation	No	Std. deviation		
Have you considered installing a GSHP system for residential heating/cooling?						
Installation cost	3.59	1.176	4.02	0.983	−1.594	0.111
Operating cost	4.35	1.057	4.27	0.898	−0.757	0.449
House market value	3.18	1.590	3.12	1.319	−0.274	0.784
Available capital	3.53	1.231	3.92	1.052	−1.366	0.172
Functional reliability	4.59	0.618	4.41	0.845	−0.644	0.519
Heating/cooling with only one system	3.65	1.656	3.93	1.068	−0.012	0.990
Equipment guarantee	4.38	0.619	4.07	0.893	−1.168	0.243
Lifetime of the system	4.75	0.447	4.47	0.641	−1.746	0.081*
Ease of installation	4.12	0.781	3.71	1.040	−1.476	0.140
Ease of use	4.29	0.686	4.00	1.029	−0.896	0.370
Thermal comfort	4.71	0.470	4.44	0.723	−1.342	0.180
Installation space	4.00	0.935	3.82	1.094	−0.496	0.620
Compatibility with lifestyle	4.29	1.105	4.18	1.013	−0.744	0.457
Environmentally friendly	4.29	1.105	4.27	0.992	−0.313	0.755
Energy consumption	4.59	1.004	4.25	0.992	−1.976	0.048**
Security during operation	4.88	0.332	4.50	0.750	−2.211	0.027**
Certainty for fuel supply	4.50	0.894	4.33	0.857	−1.130	0.259
Quality control of fuel	4.47	0.743	4.13	0.882	−1.473	0.141
Relative advantages over other systems	4.44	0.814	4.17	0.894	−1.309	0.191
Widespread technology	3.47	1.419	3.65	1.054	−0.134	0.894
Recommendations	2.82	1.185	3.14	1.104	−1.034	0.301
Time required to collect information	3.19	1.109	3.15	1.105	−0.111	0.911
Possible to see it operating before buying it	3.81	1.167	3.78	1.037	−0.278	0.781
Government subsidies/grants	3.71	1.359	3.90	1.211	−0.565	0.572
Expectations on the fuel prices	4.35	1.057	4.24	0.878	−0.940	0.347
Installation and operation standards	4.00	0.816	3.84	0.978	−0.406	0.685
Legislation on the installation process	3.37	1.147	3.68	1.114	−1.282	0.200

** Significance: $p \le 0.05$.
* Significance: $p \le 0.10$.

educational level and RES awareness. The odds someone that has awareness on RES issues to know that GSHP systems can be used for residential heating and cooling was 4.210 ($=e^{1.437}$) times greater than the odds of someone that is not informed about these issues, regardless of the other two independent variables. For each point the educational level increases, the odds of knowing that GSHP systems can be used for residential heating and cooling increased from 1.000 to 1.390 ($=e^{0.330}$), regardless of the two other independent variables.

4.4.2. *Possibility of someone considering installing a GSHP system for residential heating/cooling*

In the second model, the possibility of someone considering the installation of a GSHP system for residential heating and cooling was estimated with the help of a binary logistic regression. The dependent variable was the consideration of the installation (consider_GSHP: yes or no) and independent variables the fact that someone in the residence has an occupation or interests related to environment, technology or engineering (related: yes or no), income level (16 categories), age (age: <30, 31–39, 40–48, $49<$) awareness on RES and alternative heating/cooling systems (awareness: low, medium, or high). Level of education is represented by two independent variables; university graduate (education_univ: yes or no) and technical vocational education graduate (education_voc: yes or no). The results of the model showed that:

$$\begin{aligned}&\text{Predicted logit of (consider\_GSHP)}\\&= -15.252 + 2.844(\text{related}) - 0.835(\text{income})\\&\quad + 3.983(\text{awareness}) + 1.176(\text{age}) + 4.489(\text{education\_univ})\\&\quad + 2.803(\text{education\_voc}).\end{aligned}$$

According to the model, which explained about 61% of the variability of the dependent variable, the log of the odds of someone that had considered installing a GSHP systems for residential heating and cooling is positively related to the fact that someone in the residence has an occupation or interests related to environment, technology or engineering ($p<0.05$), to awareness on RES and alternative technologies ($p<0.01$), to age ($p<0.05$) and to the fact that someone is a university ($p<0.01$) or a technical vocational education ($p<0.05$) graduate and was negatively related to income ($p<0.01$). The odds someone that lives in a residence with a person that has an occupation or interests related to environment, technology or engineering to have considered installing a GSHP system was 17.189 ($=e^{2.844}$) times greater than the odds of someone that lives in a house where no one has an occupation or interests related to environment, technology or engineering, regardless of the other independent variables. For each point the income level increases, the odds of considering installing a GSHP decreases from 1.000 to 0.434 ($=e^{-0.835}$), regardless of the three other independent variables.

For each point awareness increases, the odds of considering installing a GSHP increases from 1.000 to 53.698 ($=e^{3.983}$), regardless of the three other independent variables. For each point age increases, the odds of considering installing a GSHP system for residential heating and cooling increase from 1.000 to 3.242 ($=e^{1.176}$), regardless of the other independent variables of the model. The odds a university graduate to have considered installing a GSHP system was 89.048 ($=e^{4.489}$) times greater than the odds of someone who is not a university graduate, while a technical vocational education graduate was 16.488 ($=e^{2.803}$) times more possible to have considered it, compared to someone that has a different educational level (regardless of the other independent variables).

5. Discussion

About 75% of the respondents declared that they were generally informed regarding environmental issues, while this percentage was

reduced by 10% regarding information on RES. As for knowing geothermal energy, the level of information was quite lower with 4 out of 10 stating that they knew this type of RES, while 2 out of 10 knew about residential use of GSHP for heating and cooling. People had been introduced to GSHP mainly through Internet, TV programs, magazines and conversations with friends.

A percentage lower than 10% stated that they had considered the possibility of installing a residential GSHP system, although during the specific survey no one was found to have eventually done it. Main reasons for not having installed the system were the relatively high installation cost and disruption of the house during the installation process.

The factors affecting the selection process of a heating system that were considered more important to the group of people that had thought of installing a GSHP system compared to the group of people that had not thought of it, are lifetime of the system, energy consumption and security during operation of the system. No differences seemed to occur between the two groups regarding the variables that represent Rogers [79] theory of innovation diffusion.

Regarding the demographic characteristics and how they affect the information levels, it was indicated that men's level of information on the fact that geothermal energy can be used for residential heating and cooling is higher than women's level. Also, educational level had a significant role on knowing about geothermal energy and GSHP, with the level of knowledge being higher as the educational levels rose.

Knowledge of these issues was also significantly affected by the existence in the residence of a person with an occupation or interests related to environment, technology or engineering. In the residences in which such a person existed, the level of knowledge about geothermal energy and GSHP, as well as the possibility of having examined the scenario of installing a residential GSHP system were much higher compared to residences in which such a person did not exist. So, the low level of GSHP technology knowledge was expected, since highly educated and those who have someone in their residence with an occupation or interests related to environment, technology or engineering were more likely to know about it.

Age influenced someone planning to install a residential GSHP system, with people from higher age groups being more possible to do so. This might be explained by the fact that older people may have their own house and the investment capital to do something like that, or even by the fact that young people are not so much involved in decisions regarding the house and by extension its heating system.

Income was negatively related to the possibility of someone considering installing a residential GSHP system. This might be explained by the fact that consumers with lower income try to be more aware and more positive on technologies that can save them money. However, although the payback period of the installation is small, the initial capital needed might be a barrier to installation. Besides, the dependent variable represents the willingness to install, and not the fact of installation.

Also, educational level had a significant role on considering installing a residential GSHP system, with the university and technical vocational education graduates being more possible to have examined the possibility of installing a residential GSHP system.

Another factor that had a significant role regarding if someone would examine the possibility of installing a residential GSHP system was information level on RES and alternative heating and cooling technologies. On the other hand, and in contrast to other studies [25,32,33,48,54,56,57,62,63,65,76], no relation was indicated between the possibility of considering installing such a system and residence characteristics such as size or year of construction of the house.

6. Conclusion

This study examined the level of consumers' awareness on GSHP technology in Greece, their perception on considering installing such a system, as well as the factors influencing the above issues. To conclude, it can be reported that even though there are few GSHP installations in Greece and the diffusion of the technology seems to be rather low, consumers seemed to be relatively informed. Of course, the economic crisis and the lack of investment capital hold back the diffusion of the technology. This happens because on one hand there is a depression of the housing construction sector, which means that there are less opportunities for the system to be installed, while on the other hand because of the high installation cost of the system and the lack of capital it is difficult for consumers to select the specific system, although it has a very short pay-back period due to its very low operation costs.

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